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TRUCK MANAGEMENT SYSTEMS REVIEW

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TRUCK MANAGEMENT SYSTEM REVIEW

by

V. Srajer

ABSTRACT

The Canada Centre for Mineral and Energy Technology (CANMET), Calgary Coal Research Laboratory and the Canadian coal mining industry are preparing a jointly funded demonstration and evaluation of an integrated truck management system. This system will be installed and tested on two rear-dump off-highway mining trucks presently operating in a producing surface coal or oil sands mine.

In the paper an overview of existing truck monitoring systems, presently available on the North American market is presented. All systems are evaluated based on their functions, diagnostics and integrated system control. The non-operator dependent on-board truck management system (OBDAS) is explained and recommended for field testing. The reasoning behind the selection of the OBDAS system is provided, as well as a discussion of the field testing proposal.

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EXAMEN D'UN SYSTÈME DE COMMANDE DE CAMION

par

V. Srajer

RÉSUMÉ

Le Centre canadien de la technologie des minéraux et de l'énergie (CANMET), prépare une démonstration et une évaluation d'un système de commande de camion intégré qui a été commandité conjointement avec le Laboratoire de recherche sur le charbon de Calgary et l'industrie d'extraction houillère canadienne. Ce système sera installé et mis à l'essai sur deux camions tous terrains, à benne basculant en arrière, qui sont actuellement en service dans une exploitation de charbon à ciel ouvert ou une exploitation de sables bitumineux.

Dans ce rapport, l'auteur donne un aperçu des systèmes de commande de camion présentement disponibles sur le marché nord-américain. Tous les systèmes de commande sont évalués d'après leur fonctionnement spécifique, le programme de diagnostic, et le système de commande intégré. L'auteur donne des explications sur le système de commande automatisé (OBDAS) qui est installé dans le camion et offre des suggestions quant aux essais sur le terrain. Il explique également les raisons qui ont motivé le choix du système OBDAS et examine la proposition relative au contrôle sur le terrain.

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INTRODUCTION

The Calgary Coal Research Labortory of the Canada Centre for Mineral and Energy Technology (CANMET) is evaluating various technological trends in Canada and abroad, to access available technology that could be applicable to the Canadian surface coal mining industry.

Many industries have demonstrated highly sophistiated and reliable systems, such as electronics and computerized control of machinery, sensing of unit operations or totally integrated data collection and management systems. CANMET attempted to collect all available information on the existing systems that could be directly applied to the trucking operation at surface coal mines in Canada.

In this report, the existing truck monitoring systems are discussed and the fully integrated data management system, is evaluated and recommended as the best system to be introduced in Canada as a jointly funded project with the Canadian coal mining industry.

AN OVERVIEW OF TRUCK MONITORING SYSTEMS

The trucking and loading operation is the backbone of the surface coal mining industry in Canada. The demand for increased productivity and lower unit cost during past decade presents challenge to mine operators. The present day trend is to employ highly sophisticated and expensive dispatch systems to control movement of the trucks, their productivity and operational and delay times. Only a limited number of mining companies have operations large enough to support such systems (1-12). The alternative is to install vehicle electronic sensors to monitor truck functions, such as speed, weight, transmission and diagnostics of maintenance problems. Only during the last several years, the total truck management systems been introduced. These systems are driver dependent, and therefore the truck operator is asked to enter data (loading, dumping, etc.) by pushing buttons on the console in the cabin (3,6,11,12) or use operators' voice commands to enter data by voice synthesis (13). This advanced and highly sophisticated technology is negated by human error of the truck operator, so the final result is quite unreliable (11,14). It has been generally accepted for some

time, that only a vehicle dependent system can eliminate human error and make this new technology more reliable.

It is recognized that certain electronic systems should be made available at competitive prices with short payback periods. Some electronic suppliers have addressed this problem and commenced the development of a range of new devices for equipment monitoring. This trend is mainly in a commercial vehicle sensing and monitoring created by the following needs:

1. optimization of human and physical resources,
2. strict environmental controls,
3. miniaturization of processing technology,
4. multiplex wiring system,
5. improved microprocessors reliability.

Only one system presently introduced (15) could provide complete solution to the problem of truck data management, dispatch and load control. Other sensing and monitoring devices could be applied for various diagnostics control of the vehicle or to collect special data on demand.

FUNCTIONS CONTROL

Current commercial vehicle electronic system address the following functions:

Speed Control

The electronic systems for speed control usually function by a solenoid valve that controls fuel pressure to the injectors, thereby limiting fuel feed to the engine. A vehicle speed sensor and an engine speed sensor transmit speed data to the electronic control unit for processing. This unit controls functions such as cruise control, torque limiting, road speed, engine speed. An example of this is the electronic engine control unit introduced by TRW Transportation Co. from Solon, Ohio (16). The speed is controlled by various devices (17), such as:

- direct engine speed sensor,
- fuel control valve,
- throttle actuator,
- brake switch,

- vehicle speed coupler,
- circuit braker,
- clutch switch,
- operator control module.

Weight Control

The need to measure axle loads to derive the optimum payload of the commercial vehicles has led to the development of electronic self-weighting systems. The sensors are placed on the vehicle axle to measure the load and weight distribution, and an on-board microprocessor provides readouts of gross vehicle payload as well as individual axle loads. The self-weighing system display is mounted in the truck cab, and provides digital readouts of axle housings and payloads weights. The measurement is performed by strain sensors located on the appropriate axles of the vehicle. The "LOADAX" system (18), introduced in 1983, is an example of a self-weighing system that satisfies the requirements of holding the load below the legal maximum limit and yet maintaining the load close to the limit for efficient truck operation.

Another example is the loader dependent device, installed on shovels or loaders (19,20). The system, installed on the Bucyrus-Erie shovel at the Lornex Mine in B.C., consists of a module that tells the shovel operator when the truck is fully loaded. The module's microprocessor uses electrical signals from three motors in the shovel to calculate the weight of the load. It measures each dipper load accurately as it is placed in a truck. The accumulated load is presented to the shovel operator on a display unit inside the cab. At the end of the shift, a data printout is produced that includes the weight of the material moved, weight carried by each type of truck, the number of dippers to load a truck and time taken for loading.

Fuel Control

This system was first introduced as fuel recorder for use on interstate trucks (17) to measure distance, time and fuel usage for calculating of tax rates in the United States. When crossing the state boundary, the delay caused by the state tax authorities check was minimized, because the data on fuel consumption were recorded and made available on demand.

A similar sensing system is now used on commercial vehicles elsewhere to calculate and monitor fuel level and provide reporting on the fuel consumption.

Trip Recorders

All electronic trip recorder, developed by TRW Engineering (17) use recorded engine and vehicle speed to show the percentage time of the vehicle operation under different conditions (idle, over speed limit, RPM, etc.). The recorder provides a means of reviewing the haulage profile and permits the operator to optimize vehicle utilization and scheduling.

Transmission Control

The electronic control is available for both manual and automatic transmissions. In a manual system the driver manually changes gears, but the clutching action is done automatically in the system. This allows for smoother shifting through the gear range and improve the driveability by shortening the shift transition time. With automatic transmissions, the program of selectable shifting was introduced by the Detroit Diesel Allison Divison of GMC (21). A microprocessor control unit is controlling and electro-hydraulic valve body, shift selection, digital display unit, throttle sensor and output speed sensor.

Tire Pressure Control

A system that automatically maintains proper tire pressure was introduced by Automotive Products Division of Schrader Co., Nashville, Tennessee (22). The system is a combination of three basic components, utilizing the excess compressed air available in the braking system, to constantly monitor and regulate the air pressure in each tire. These components are:

- Control Box - Monitors tire pressure and feeds regulated air through the axle and rotating joints.
- Rotating HUB - Forms a connection between tire axle and tire valves, permitting constant tire pressure regulation and air pressure maintenance.
- Warning Light - A warning signal is given if the tire pressure drops below a pre-set minimum. It is actuated by the control box.

The tire pressure control is installed by making connections to the tire valves by drilling through the front-end spindle and connecting over the side in the rear. The control was installed on Wabco-75, Euclid-R75 and Terex 33-15 haulers. It is also available as an option for Kress CH-100 bottom-dump coal haulers.

DIAGNOSTICS CONTROL

The electronic maintenance and diagnostics technology has advanced considerably during last five years and there are many diagnostics systems installed on various commercial vehicles - too many to mention all. As an example, a mechanic can check out a vehicle's cruise and speed control system in less than five minutes (16) with a diagnostic unit that plugs into a control module. Also, the operator can check the truck's starting and changing system with a single piece analyser that plugs into the instrument cluster (23). It is understood that every truck electronic system available today has a corresponding diagnostic system.

One of the well designed electronic diagnostics systems available today was developed by Fuel Technology Division, Gelco Truck Leasing (17). The experimental system was installed on a test vehicles and is under continuous testing. The purpose of the tests is to develop diagnostic system components that will withstand (24):

- temperatures ranging from -40°C to +125°C,
- steam up to 1400 kPa,
- liquid pressure wash up to 5200 kPa,
- humidity from 0 to 100% at ambient temperature, and frost at -40°C,
- peak vibration of 50 G's,
- sand and gravel throw damage,
- contact with toxic fluids, such as diesel fuel, transmission fluid, anti-freeze, paint, brake fluid, cleaning solvents, etc.

Regardless of the capacities of the individual components of a truck electronic system, the system itself is required to be expandable and versatile. One of the systems that seems to fulfil this requirement was described by (25). This system was designed to accept future microprocessor units without the need to redesign the original system.

Three diagnostic control systems were identified as examples in this category:

1. EEC-IV, developed by Ford Motor Company,
2. FMS-1330, developed by ARGO,
3. TSS, developed by Dynafloat.

The functional description of these three examples follows:

EEC-IV System

This system, a fourth generation electronic engine control microcomputer, was developed by the Ford Motor Company in 1983 to provide microprocessor-based electronics for 1984 model of all spark-ignition passenger cars. This system was designed to replace a device installed at 1963 model cars, that virtually eliminated crankcase emissions. The gases in the crankcase were recirculated back into the engine's induction system using a closed positive crankase ventilation (PCV) system. Later in 1978, the "Corporate Average Fuel Economy" (CAFE) standards were introduced and a variety of systems and devices were needed to control exhaust emissions. Simultaneous control of all components of exhaust emissions were becoming increasingly complex and requires the use of microprocessors to provide a more optimum engine control strategy than was possible with mechanical control.

The EEC-IV systems were first installed on Ford Escort and Lynx cars, having engine size of 1.6 litre only. The following sensors were installed:

- enginer coolant temperature,
- throttle position,
- exhaust gas oxgyen,
- vane air flow and temperature,
- air conditioning clutch,
- neutral/drive switch,
- self test sensor.

The system capability was tested through the following functions:

- fuel control,
- spark control,
- canister purge,

- idle speed control,
- self diagnostics,
- fuel shut-off,
- AC power cut-off.

The microprocessor uses a 64K memory address, having 20 output channels, an on-chip analog-to-digital (AID) converter and two high speed I/O co-processors.

Other car and microprocessor manufacturers introduced their own microcomputers for applications in the automotive electronics. An overview of the selected microcomputers is presented in Table 1 (26). This Table is not intended to be a complete listing of all microcomputer products to date. It only serves to indicate some innovative applications of microprocessors by automotive manufacturers over the past decade.

Installation of microcomputers increased during the last five years. Cars are introduced in the market, having five or more microcomputers on board (26). The present day trend for commercial and off-highway vehicle installation is an advanced engine control, especially after the introduction of diesel engine microcomputers in 1985 (26). The trend is in refining engine performance, increased use of turbochargers, introduction of the continuously variable transmission (CVT), advanced comfort and convenience control, instrument panel control and new display technology.

FMS-1330 System

The FMS-1330 fleet management system is an automated diagnostic tool which data can be retrieved the moment a vehicle returns to the shop (27). The cartridge is removed from operator's cabin and placed into the reader unit in the mine office. The following information can be obtained:

- fuel consumption,
- overspeeding,
- engine operation,
- driving and stopping habits,
- excessive engine idling,
- whether speed, RPMs and engine idling are within the criteria set for economical use of the vehicle.

Table 1 - Selected microcomputers applications

Year introduced	Manufacturer	Trade name	Microcomputer technology	Features/remarks
1977	GM	MISAR	Rockwell PMOS	First engine control microcomputer
1978	GM	Trip-computer	Motorola	Digital gas discharge
	Ford	EEC-1	Toshiba	Interactive engine control
1979	GM	C4	Motorola	Air/fuel microcomputer control
	Ford	EEC-11	Toshiba	Multifunctional engine control
	Chrysler	DSIC	RCA	Multifuncational engine control
	GM	ERT/CB	TMS	Microcomputer radio control
	GM	Trip-computer	Motorola	Digital display
1980	GM	C4	Motorola	In-line diagnostics
	GM	FDC	Mostek	HVAC control
	GM	DEF-1	Motorola	Fuel injection control
	Ford	EEC-11	Motorola	Carburetor control
	Bosch	Motronic	RCA	Fuel injection control
	Nissan	ECCS	Hitachi	Fuel injection control
	Ford	MCU-A	Intel	Engine control
1981	GM	C3	Motorola	Transmission torgue control
	GM	DEFI	Motorola	Engine & cruise control
	Chrysler	CEFI	RCA	Fuel injection control
	Mitsubishi	ECI	NEC	Vortex MAF sensor
1982	GM	TBI	Motorola	A/C clutch control
	GM	C3	Motorola	Turbo spark knock control
	Bosch	LH-Jetronic	AMI	MAF control
	Isuzu	ITEC	Hitachi	MAF sensor
	Honda	Gyrocater	TMS	Automotive navigation system
	Toyota	A43DE	Fujitsu	Automatic transmission control

The distance is reassigned and compared with the scheduled route. The driving time is compared with the scheduled operating time, calculating utilization of the vehicle and thus it provides an indication of the vehicle productivity. A report is produced showing "red flag alert" data, when preset standard such as speed limit, fuel consumption, etc., are exceeded. In the report, the event description includes messages such as "SPEED VIOLATION", "RPM VIOLATION", "IDLING VIOLATION", giving details on distance, duration and time of the occurrence of the "red flag" event. If a driver has failed to meet preset standards, then the longest violations will be automatically printed as explicit single event recording.

Another event for close monitoring could be chosen, such as low engine oil pressure, high water temperature, exhaust gas temperature,number of brake applications, etc. Up to fifteen recordings could be reported.

The hardware for this system, developed by Argo Instruments Inc. in 1983, consists of:

- Data cartridge (2K byte storage capacity),
- Microcomputer (TRS-80 Radio-Shack Model 12),
- Printer (DMP-400 Dot matrix),
- Operating system (Oasis, Phase 1, Tandy software).

This FMS-1330 system was installed on leased long-distance highway trailers in Canada and U.S.A. and on vehicles operated by Ruhr Mining Company in West Germany.

TSS System

The TSS system (Truck System Simulation) was developed by Dynafloat Inc., a subsidiary of Unit Rig's Co. of Tulsa, Oklahoma. Here, simulation is designed for controlled environment electronic testing and/or adjustment of the complete panel functions (28). The TSS permits bench testing of the electronic control panels for General Electric reliance systems used in various trucks.

The program developed is used to monitor the Lectra haul truck performance, from the manufacturing process to the breakdowns in the field. The quality assurance information system consists of four subsystems which provide critical information:

- inspection reports to truck manufacturing problem,
- product component failure report to track field failures,
- warranty report to track all failures under warranty,
- quality analysis report to provide data on quality costs.

The system provided a 5% reduction in operating problems, improved reliability and availability of truck fleet. The system was installed on Lectra haul M-85 trucks working at Toquepala Mine in Peru and on electric drive haul trucks at the Konnecott Minerals Co., Chino Mine in New Mexico.

The TSS system could be installed at any diesel/electric truck using either the General Electric or Reliance Electrical system. These trucks are equipped with a diesel engine that actuates a generator or an alternator. The generator/alternator in turn powers the wheel motor. The card rack with printed circuit boards control the motoring and retarding of the truck. The rack can be set to fit the needs of an individual truck, based on component wear of the engine and so on.

INTEGRATED CONTROL SYSTEMS

Integrated control systems, presently installed or under development by various transportation or electronics companies, are explained here. These electronics control systems are installed on each truck individually and are not the integral part of the overall mine dispatch system. The truck dispatching, that uses a direct message system, controlling allocation of trucks and at the same time collects data on driver performance and vehicle utilization. This is however beyond the scope of this report. An overview of the dispatch system and its application to the Canadian mining industry as a separate report will be available shortly.

Several typical fully integrated control systems were identified and are described as follows:

TIACS System

The TIACS system (Truck Information and Control System) was developed by TRW Transportation, Electrical and Electronics Operations Division of Solon, Ohio. It integrates several functional controls developed by the same company as mentioned earlier in the text, into a single fully integrated unit.

This system was built for the industry interested to optimize vehicle performance, accomplish effective use of materials and use of advanced technology including electronics (29). A highly innovative vehicle monitoring system was designed, having the following unique characteristics:

- time-sharing of certain system components,
- multiple uses and service conditions by individual operators,
- easy modification and addition to the existing system,
- recording and monitoring capability for improved asset management and reduction of diagnostic and maintenance costs,
- programmed rebuilding-overhauling schedules,
- introduction of new technologies when current systems are obsolete without a major disruption to the basic vehicle system,
- system flexibility for options.

The TIACS has one basic element called Serial Communications Link Based System (SCL). This system provides link for reliable data transfer between vehicle sensor, actuators and control systems. The SCC will allow various electronic systems and sub-systems to communicate, exchange data and cooperate when certain systems can act independent of a master control unit if required. Features of the SCL are: (Fig. 1)

- use of a shared line,
- random access,
- bi-directional data transfer,
- multiple types and variable length message,
- error detection capacity,
- compatability with future subsystems.

A complete set of truck electronic sub-systems of the TIACS system is divided into the following categories:

- driver comfort,
- driver and vehicle safety,
- performance monitoring and controls,
- information displays,
- vehicle maintenance and diagnostics.

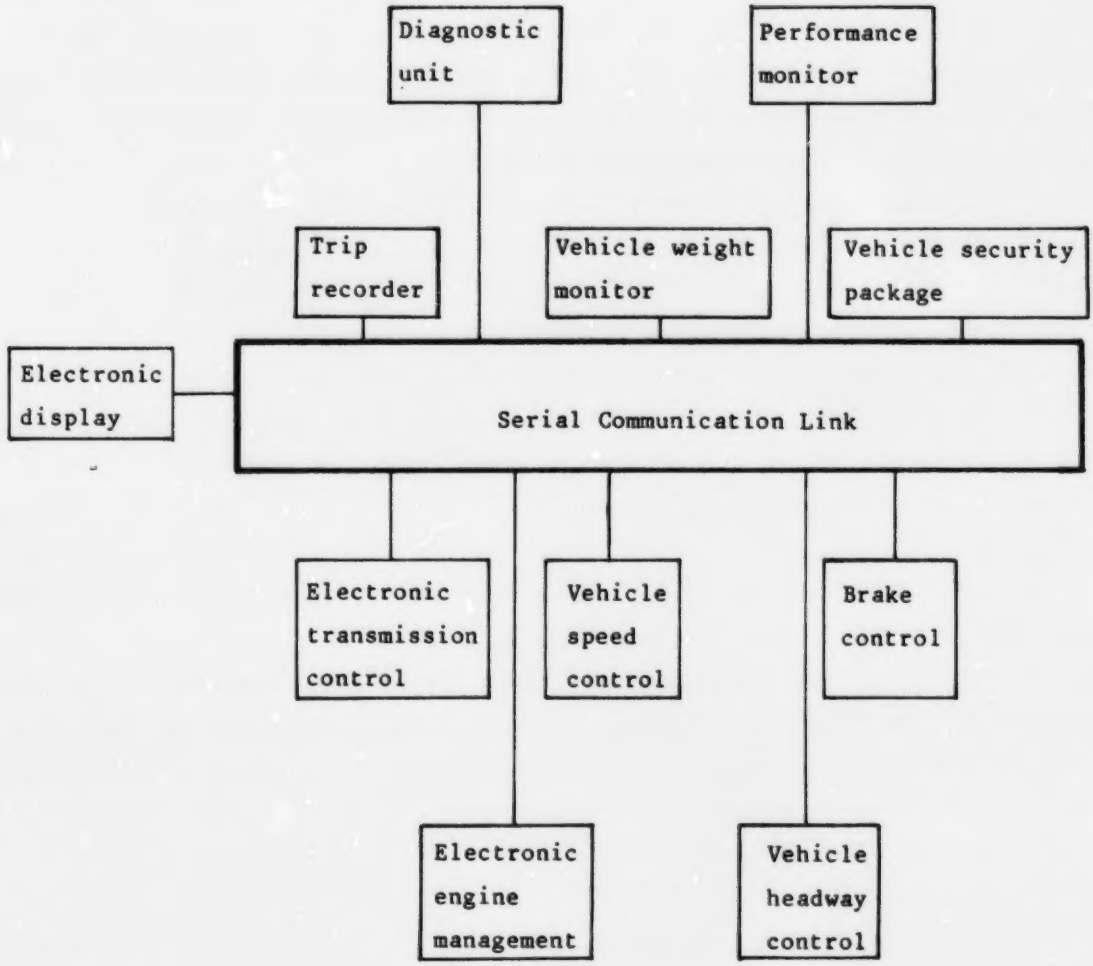

Fig. 1 - A SCL (Serial Communication Link)

Driver Comfort System connected to the TIACS serial communications link include "power steering assist", climate control and electronic seat control.

Driver and Vehicle Safety System includes collision warning system, engine protection system, crash recorder, drowsy driver warning, vehicle security package, road conditions monitor, anti-skid and sequential braking module and trailer docking collison module.

Vehicle Performance Monitors and Control Systems include performance monitor, air deflector control, trailer load monitor, engine cooling control, auxiliary hydraulic system controls, electronic fuel management, torque/drive load sensing monitor, fifth wheel hook-up assist, trailer jack assist and tire pressure monitor.

Information Display System includes four different types of electronic displays: digital, analog, alpha-numeric or annunciator. Each type is matched to a specific type of information displayed.

Vehicle Maintenance and Diagnostic System includes "fuel tax" recorder, maintenance monitor and diagnostic/warranty monitor.

The TIACS system is capable to incorporate the Serial Communication Link and microprocessor-based system plus advanced electronic technologies available in future, namely voice synthesis, satellite-based navigation-location and advanced displays.

The TIACS system was introduced to the automotive industry in 1983. The system is partially developed at the present time, when several components were installeed and tested. The performance monitor, vehicle speed control, diagnostic unit, engine and transmission control and trip recorder were successfully tested at large tractor-trailer units in U.S.A. The vehicle security and brake control packages were under development during 1985.

VMS System

The Vehicle Monitoring System (VMS) was introduced as a preventive maintenance tool to reduce downtime and repair cost (30). The system was developed by GLI Corporation, a subsidiary of a Baker Mining Equipment Company of Woodinville, WA. The system consists of a flexible microprocessor based unit that continuously monitors engine, drive train and all vital functions including pressures as well as fluid levels, temperatures, electrical

outputs, RPM and speed of the vehicle. Sensors are provided for the specific function monitored and alarm could be set to a limit adjusted to meet operating conditions (Fig. 2)(31).

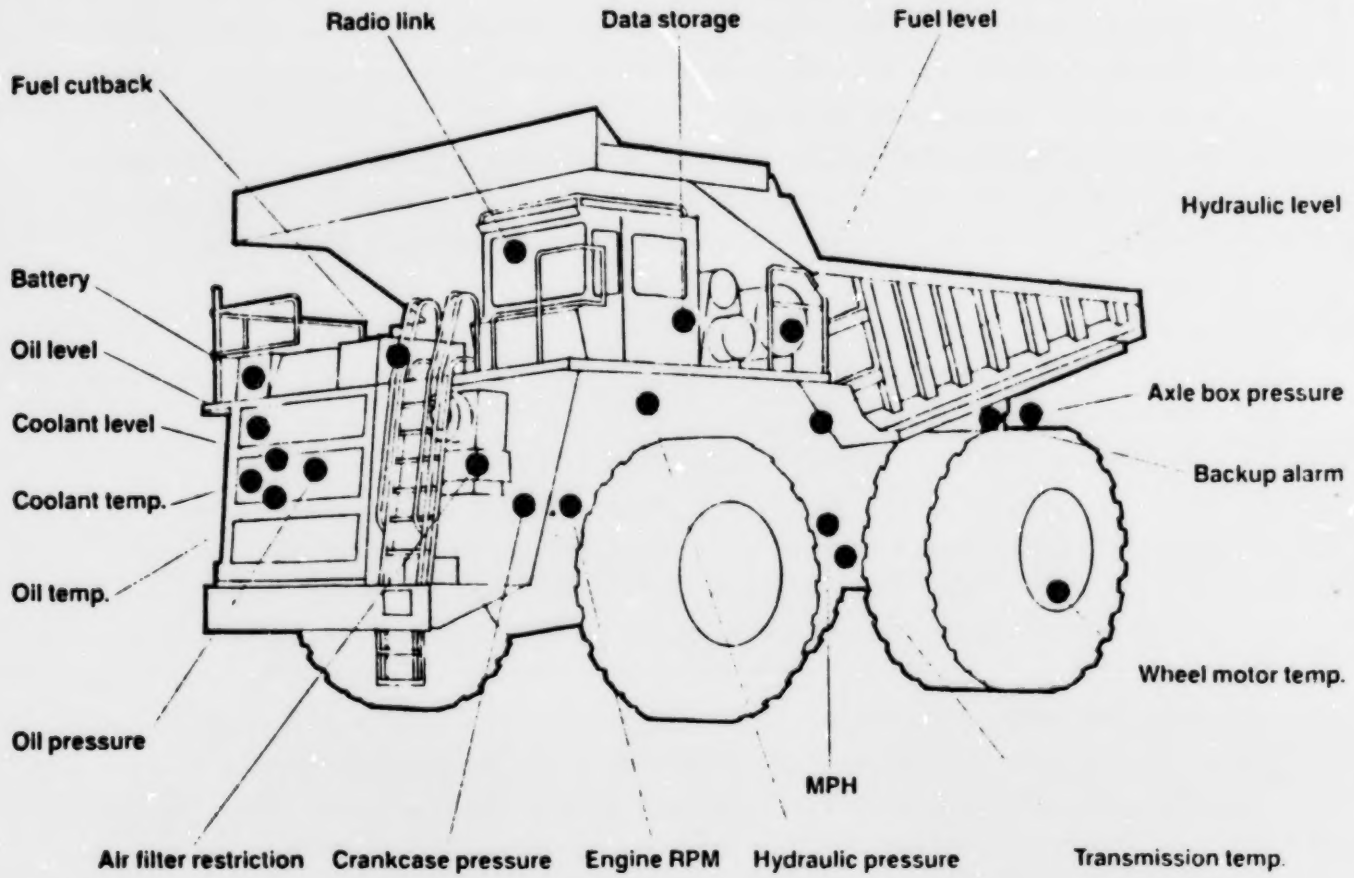

Fig. 2 - VMS system monitors

The VMS system is designed in such a way that the operator is not distracted, rather, told specifically the nature of the problem and the action to be taken when such a problem occurs. During normal conditions, the display in the cabin shows a constant readout of a particular chosen parameter, such as engine RPM. In the event of out-of-limit condition, a "critical" alarm informs the operator by visual or audible means the nature of the critical event and the appropriate action to be taken to correct the condition.

The system also provides information to mine maintenance personnel, assist them in trouble-shooting. It could be placed in "TEST" mode when all monitored functions can be displayed individually and operating values can be compared to monitored values. On-board memory continuously records operating extremes and their duration giving maintenance personnel a view in time of vehicle performance.

The VMS has the capability to be linked to a radio system which allows it to communicate with a central dispatch office for real-time equipment management. Also, a data logger, rather than a radio link, can be used to store operational history and analyse it at chosen intervals. This data can be retained or combined with other maintenance records for trend analysis and histogram preparation.

The VMS system feature:

- data output - an RS-232 port is available,
- minimal installation downtime in field,
- alarm limit adjustable to special requirement,
- inputs of up to 40 measurements,
- easy trouble shooting by the self-test of system electronics and sensors,
- field service program backing.

The VMS system was installed in 1984 an is still tested in the field, using Caterpillar and Wabco trucks employed at one mine in Ohio.

ETEC System

The ETEC or Electonic Engine Control system is an intergral part of an Automatic Truck Control system introduced by TRW's Transportation, Electronics Division, Farnington Hills, Michigan (32). The ETEC System provides:

- controls for vehicle speed on established limits that are programmed into the ETEC calibration module,
- cruise control to provide a complete vehicle/engine speed management,
- engine speed limiter to limit engine speed through all of the gears, encouraging the operator to use the highest, most fuel-efficient gear at all times.

The electronic recorder used with the ETEC system (33) is a vehicle monitoring device which produces reports on vehicle usage. The reports informs the user on ETEC system control mode settings, indicates time at idle between trips, shows total elapsed trip time, provides summary records of average speed, trip summary records of total kilometer per day, date and date changes during trip, vehicle speed-RPM report, detailed/summary trip reports, trip report with ETEC system modes and trip faults report. The data recorded could be transferred to IBM-XT personal computer for further evaluation.

The ETEC and the Automatic Truck Control (ATC) systems were installed at Unit-Rig Lectra haulers, type M-100. The prototype, developed in construction with SAAB-Scania Company, was first tested at Unit Rig's test track in Tulsa, Oklahoma and displayed publicly at the 1974 Mining Equipment Convention in Les Vegas (34). Since 1976 the system was constantly redesigned to maximize reliability, ease of maintenance and to accommodate additional controls.

The basic system consists of the "On-board control" equipment and the "Wayside control" equipment. The On-board equipment receive commands from the Wayside equipment and controls all the truck functions. In addition, on-board sensors monitor all critical truck functions and provide instruction to the truck and system to assure safe operation.

The Wayside equipment is a buried guidewire block control unit and a central controller which provides predetermined signals to the on-board equipment for speed control, steering and for auxiliary functions (dumping, horn, signal, etc.) by using guidewire located in the truck's path. The wayside equipment also controls vehicle separation, system status and provides truck location to a central display panel. The central control panel can vary the speed level signals over any road segment and also command an emergency stop of the unit (Fig. 3).

At the present time, the ATC system is under extended test. Five M-100 Lectra haul trucks are equipped with ATC equipment and are operating in a mine stripping operation. Data are gathered to assess reliability, availability, operating and maintenance costs. The ATC equipped trucks productivity is compared with a standard trucks to evaluate the equipment for application in mines. Designed reliability level of 95% is required before the ATC system will be made available to the mining industry.

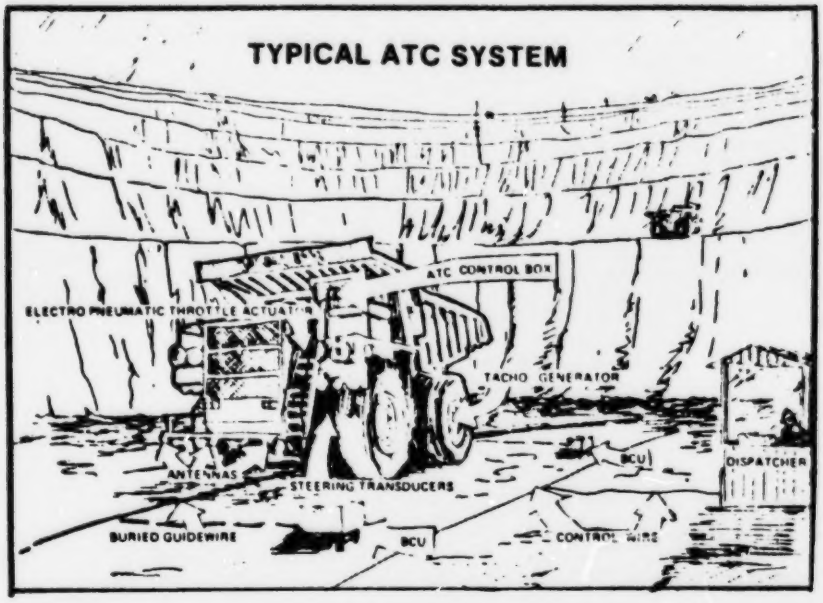

Fig. 3 - A typical ATC system

TRUCK MANAGEMENT SYSTEMS

The truck management system is an information concept that include:

- truck operational/maintenance management,
- on-board functional sensing and diagnostics,
- truck dispatch.

The data into the system for evaluation and decision making are entered automatically and independent of the operator.

A truck management system, at the present time the only one reliable and working on prototype, was developed by Philippi-Hagenbuch, Inc. of Peoria, Illinois (15). The concept consist of an automated data gathering system, forming a factor-building blocks, such as weighting, time and motion study, maintenance management, as well as truck dispatch.

Information that is provided by the standard system, called "OBDAS" is as follows (Fig. 4)(35):

- payload hauled per load cycle,
- haul cycle time,
- haul cycle time segments including:
  - . time to load,
  - . loaded time to dump,
  - . time to dump load,
  - . return time,
  - . identification of all other haul cycle time segments,
- total tonnage hauled per day,
- number of loads hauled per day,
- average load hauled,
- average haul cycle time,
- time truck started,
- truck number,
- operator number,
- date.

The "OBDAS" system concists of two body-to-chassis frame rail load sensors, a 3-position micro switch, a mercury tilt switch and a microprocessor. The basic load sensor is a pressure hose, clamped on either end, filled with oil with high accuracy pressure transducers on either hose end. These load sensors replace the frame pads, so as the body is loaded, pressure builds in the hose and the pressure transducers transform this pressure to the microprocessor for correlation.

Travel direction and time in each gear range - forward, neutral and reverse - is obtained by three position micro switch, while dump body actuation is obtained through output by a mercury tilt switch. The information on truck performance is provided by compiling the input from load sensors, the 3-position micro switch, the mercury tilt switch and the operator dialed-in truck/operator number. The microprocessor continually samples each input and develops accurate truck performance data so, with an understanding of what is occurring, improvements may be introduced.

The accuracy of the OBDAS system is specified to be in $\pm$2% range (35), therefore this system could provide a competitive edge to greater, improved efficiency of the trucking operation.

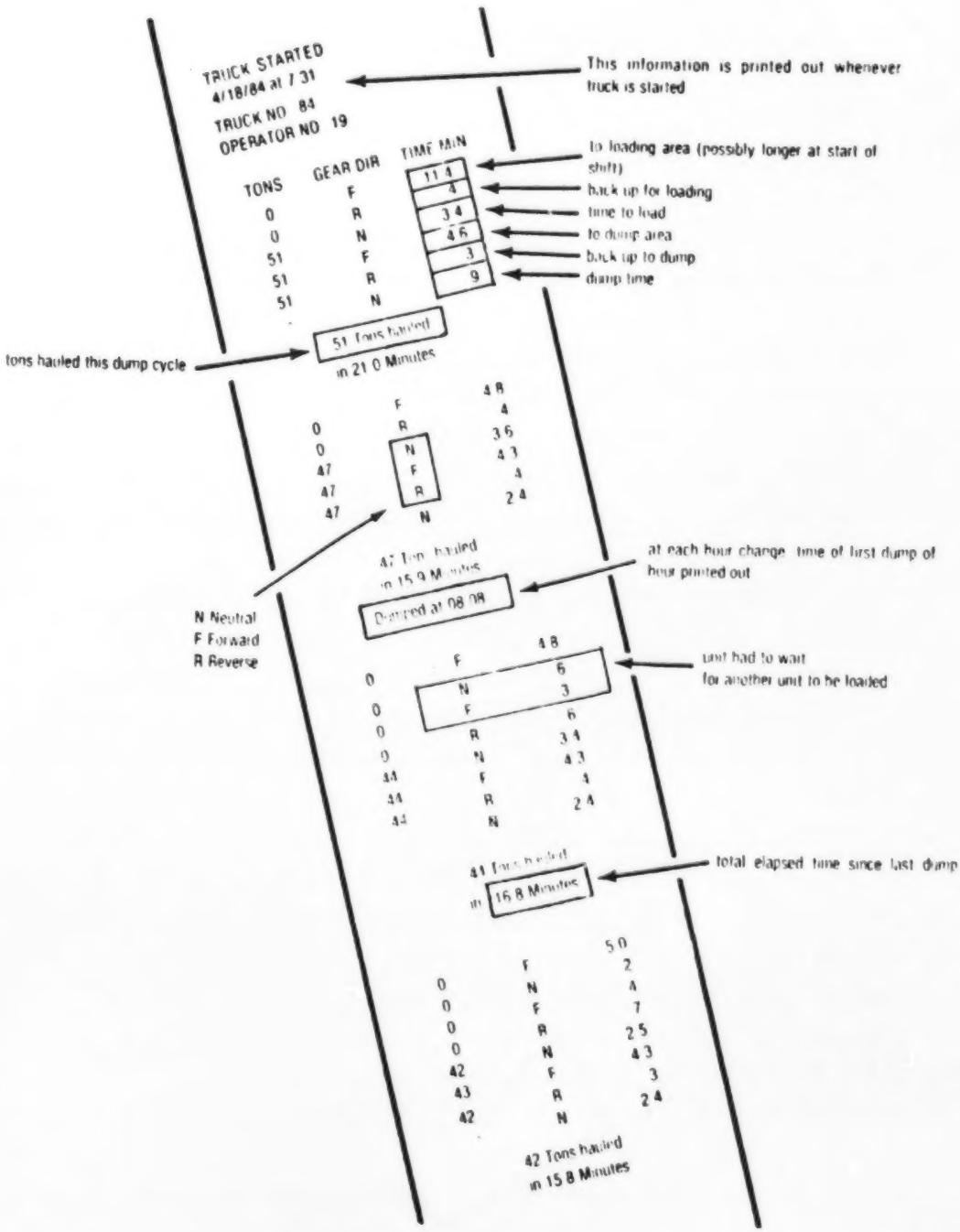
TRUCK STARTED
4/18/84 at 7 31
TRUCK NO 84
OPERATOR NO 19
This information is printed out whenever truck is started
TONS
GEAR DIR
TIME MIN
0 F 11 4
0 R 4
0 N 3 4
51 F 4 6
51 R 3
51 N 9
To loading area (possibly longer at start of shift)
back up for loading
time to load
to dump area
back up to dump
dump time
51 Tons hauled in 21 0 Minutes
tons hauled this dump cycle
0 F 4 8
0 R 4
47 N 3 6
47 F 4 3
47 R 1
N 2 4
42 Tons hauled in 15 9 Minutes
Dumped at 08 08
at each hour change time of first dump of hour printed out
N Neutral
F Forward
R Reverse
0 F 4 8
0 N 6
0 F 3
0 R 6
0 N 3 4
44 F 4 3
44 R 1
44 N 2 4
unit had to wait for another unit to be loaded
41 Tons hauled in 16 8 Minutes
total elapsed time since last dump
0 F 5 0
0 N 2
0 F 4
0 R 7
0 N 2 5
42 F 4 3
43 R 3
42 N 2 4
42 Tons hauled in 15 8 Minutes

Fig. 4 - Example of information provided by OBDAS system

Only once the microprocessor keypad is used - to input vehicle control number status for indicating truck in/out of service status. The automatic gathering system could also feed information into a central control computer, by adding the following system components:

- RF data link modem on each truck,
- RF data link modem on each loading equipment and on dump site,
- microprocessor on each loading equipment.

With a RF data bit modem on each truck, the automatic feeding of data to a central control computer is possible. An overview of this system is illustrated in Fig. 5. The data are generated on the truck and downloaded to a central control computer. In the real time, using RF data link modems to collect information for a central truck management system, the basic building blocks for truck tracking information are established.

By using the same system, the truck could be located by using:

- smart sign posts that transmits information onto the central control computer or,
- by non-intelligent sign posts that merely indicate to the truck its location and the truck then transmits it to the central computer.

If an odometer is added to the data gathering system, the microprocessor can calculate the distance travelled in any directional segment. The output is then:

- tons on truck at gear directional change,
- direction of vehicle travelled,
- time vehicle travelled in each direction,
- distance vehicle travelled in each direction.

By adding the fuel consumption indicator, the fuel used by the loaded or empty truck, and fuel used per unit time or per tonnage moved, could be provided.

There are four primary data files for each truck or loader/shovel on dump site (15):

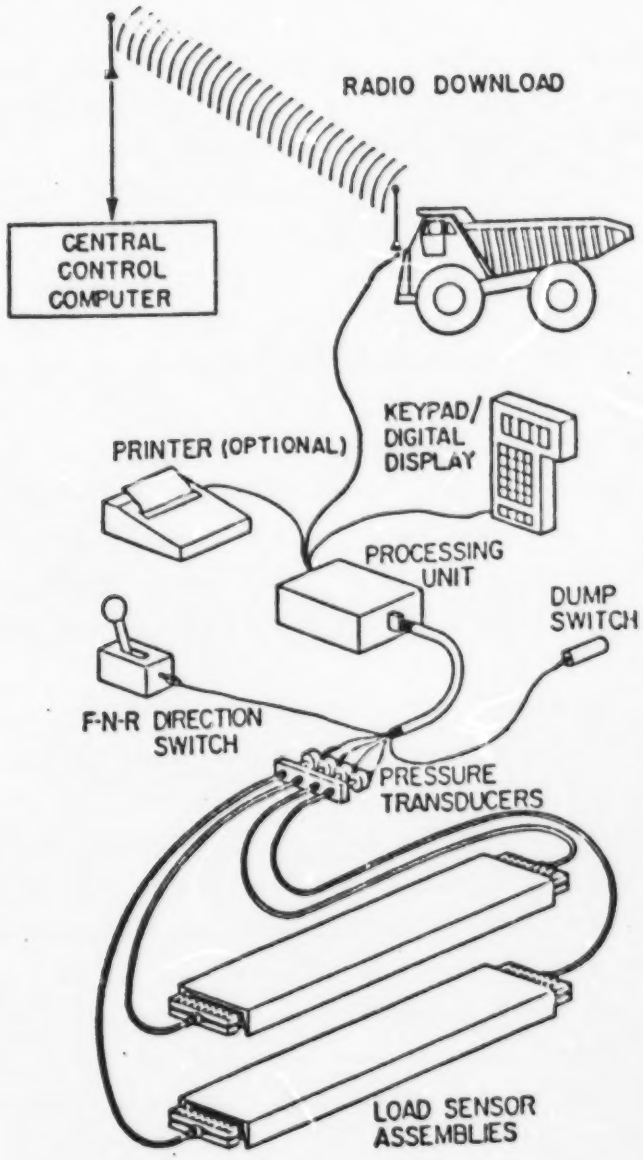

Fig. 5 - Down-loading of information to central control

- Loading time - for each class of trucks with each possible class of loading equipment, from first bucket loaded into the truck to the time when truck leaves loading site.
- Loaded haul time - for each class of trucks from each possible loading site to each possible dump site, including time to dump, i.e. from the time each truck pulls away from a loading site until the dump/body tilt switch signals truck dump.
- Empty return time - for each class of trucks from each possible dump site to each possible piece of loading equipment including time to back-up for loading but excluding any waiting time, from the time when the dump/body tilt switch signals the load has been dumped until the load sensors indicate placement of the first bucket in the truck. A subfile in this primary data file can be maintained for the time spent in queuing at the loading site.
- Total haul cycle time - for each class of trucks from each possible piece of loading equipment to each possible dump site, from the time between subsequent dump/body tilt switch signals or time from dump to dump (nominally, total time stored in date files).

As the four primary data files are established they are updated and new data are generated by the building blocks of the system, i.e. load/weighing sensors, the transmission/vehicle direction monitor, etc.

The process of data file updating is continuous as loading continues and haul road conditions change to provide for orderly updating of the data files. The data matrices are established for each possible truck, loading equipment and dump site combination. The data matrix is of two basic sizes, one for loaders and one for shovels. As rubber tired loaders are normally much more mobile, travel times to and from them are more prevalent to change while shovel location is fairly fixed so the shovel movement occurrs on a more gradual basis.

Figure 6 illustrates a total system assembly, showing sensors and indicators installed on the truck to collect and process input data.

The basic core building block information needed to set up a good Truck Management Information System (MIS) is illustrated in Table 2 (15).

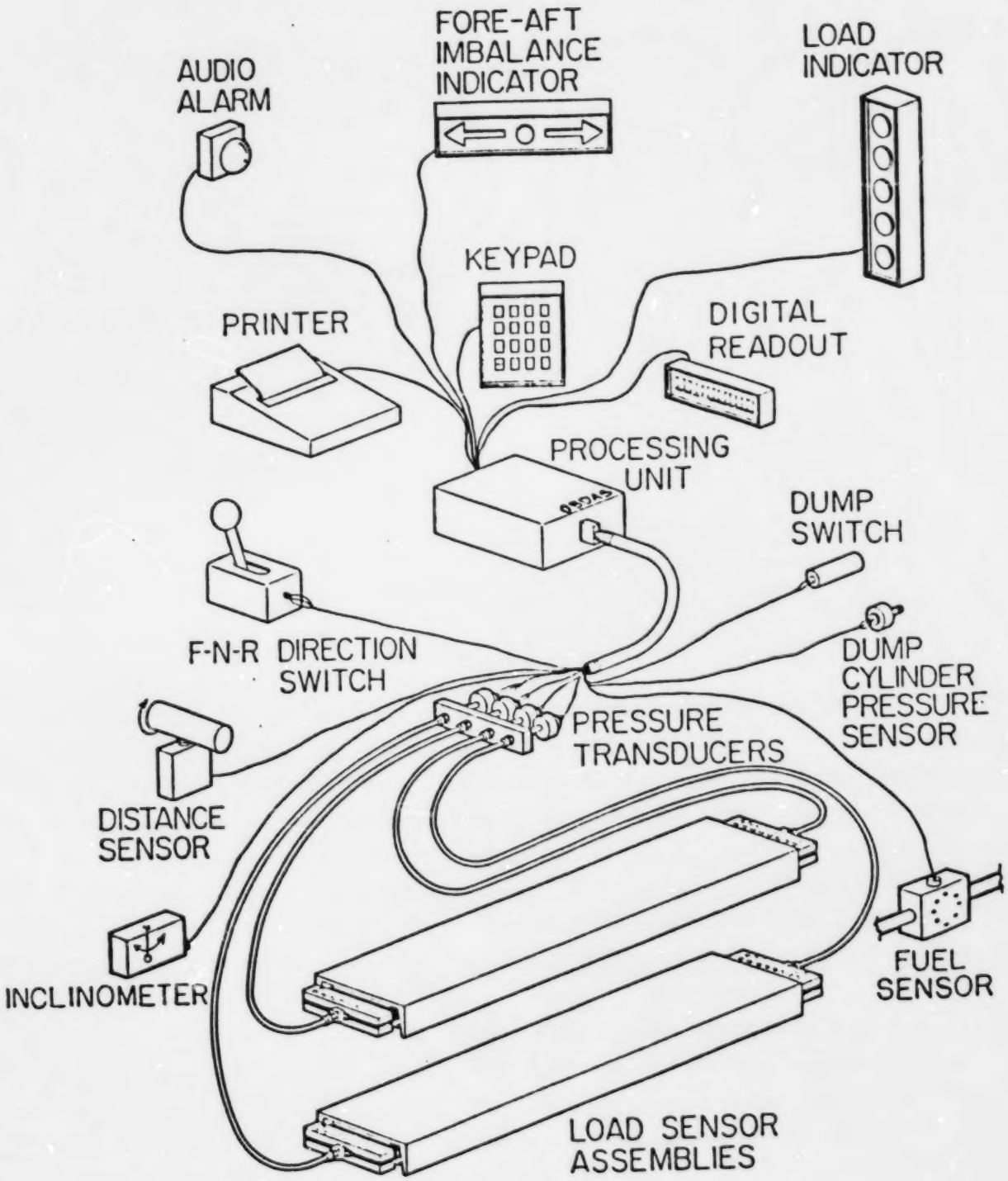

Fig. 6 - OBDAS system input sensors and indicators

Table 2 - Basic core building blocks of OBDAS system

Information needed	How information is obtained
Time	- On-board microprocessor
Haul cycle segments	- Transmission/vehicle direction monitor
Truck status	
. being loaded	- Loaded/weighing sensors
. loaded	- Loaded/weighing sensors
. unloaded	- Dump/body tilt switch
. in service	- Microprocessor keypad
. out of service	- Microprocessor keypad
Vehicle location	- RF data link modem
Loading equipment status	
. in service	- RF data link modem repeater
. out of service	- RF data link modem repeater
Optional	
. distance travelled in each haul segment	- Odometer
Fuel consumption	- Fuel sensor

Paramout to understanding the concept of an integrated truck management information system is therefore automated data gathering and down-loading. By using an automated data gathering, an accurate dispatch system is possible. A system is set up with load/weighing sensors, dump/body tilt switch, transmission/vehicle direction monitor and time sensor. The microprocessor can then identify load hauled, hauling time, delay times, loading equipment status and the fuel consumption. The RF data link modem can down-load data to a central control computer, that will allow mine management to:

- see mine production and make changes to it,
- change and assign equipment to reduce delay times and improve production,
- improve efficiency of the system.

FIELD TESTING PROPOSAL

After identification of all available data gathering and truck management systems, a jointly funded demonstration and evaluation of an integrated truck management system in a producing Canadian surface coal or oil sands mine was developed.

It is proposed to acquire OBDAS system, install it on two off-highway vehicles at the mine and evaluate the system in an operating environment. The system was specified to collect the following information:

- payload hauled per load cycle,
- haul cycle time segments including:
  - . time to load,
  - . loaded time to dump,
  - . time to dump load,
  - . return time to be loaded,
  - . an identification of all other haul cycle time segments,
- details of truck operation including:
  - . vehicle speed,
  - . roadway inclination and elevation,
  - . gear in use,
  - . gear changes,
  - . rate of fuel consumption,
  - . TKPH rate,
  - . vehicle direction (forward/reverse),
  - . time and date.

It was also specified that the data elements must be manipulated to provide accurate averages for different time segments, total times, trends and other relevant data manipulations for performance analysis. Some method of defining truck position within three dimensional space and relating position back to the above data elements would be advantageous.

The data from the various sensors must be stored in a format suitable for data entry to a base computer. The sensors and microprocessor must in combination result in an accurate, repeatable and reliable system that can cope with the harsh operating conditions experiened by the off-highway trucks. The system should also indicate to the operator the

system status and relevant outputs such as:

- load indicator with series of lights for loader operator to see,
- FORE-AFT imbalance indicator - 3 lights system to show load balance,
- audible alarm if load is off centre,
- dump cylinder pressure sensor that gives ton-kilometer, body-up indicator and haulroad profile,
- haul back monitor that will signal driver when truck bed cleaning is needed.

The following work statement was prepared and send to potential tenders in the contract proposal.

1. In consultation with the Scientific Authority, the contractor will assess and select the most suitable integrated off-highway truck management system for demonstration and evaluation.
2. Following written confirmation from the Scientific Authority, the contractor will obtain and install the selected system on at least two plus 100 tonne rear dump off-highway trucks.
3. Following commissioning of the system, the contractor will place the two similarly are equipped vehicles in normal production for six months and assess the performance of the integrated off-highway truck management system. This assessment will include as a minimum:
   . an evaluation of the reliability, repeatability, accuracy, and utility of the various system outputs,
   . a comparison of system generated data with visual time study collected data,
   . an assessment of the significance of the outputs to enhanced productivity/reduced operating costs in Canadian open pit coal and oil sands mines, and
   . an overall review of the 6 month trial including emphasis on problems and succcesses of the work.
4. The trial must be scheduled so that both winter and summer conditions are encountered (i.e. February to July or August to January for example).

5. It is recognized that such a demonstration project contains an element of risk. Should the selected system prove unacceptable to the contractor at any time, the Scientific Authority and contractor may agree to the premature cancellation of the trial for reasonable grounds.
6. Copies of all data generated by the integrated truck management system will be provided by the contractor to Calgary CRL in a computer based format suitable for data entry on the Calgary CRL VAX-11/750 (suitably formatted tape is the preferred medium).
7. The Scientific Authority will visit the contractor's mine site at least monthly to assist the contractor in the conduct of this investigation.

The Coal Research Laboratories decided to demonstrate this integrated truck management system in a producing Canadian open pit coal or oil sands mine in order to exchange operational awareness of truck performance, resulting in improved management information and control, which will lead to improved vehicle productivity and reduced cost.

CONCLUSION

This report provides overview of existing truck management and data gathering systems available in North America and directly applicable to Canadian surface coal or oil sands mines. Highly advanced truck dispatch systems were identified in the report, but no attempt has been made to describe these systems here. Only on-board installed data collection systems are described in this report, because these devices are readily available and are affordable to most producing companies in Canada.

The truck monitoring systems were divided into three categories, based on their applications for functional, diagnostics or integrated system controls.

The functional control systems identified are:

- for speed control: electronic engine control unit (TRW),
- for weight control: Loadax system (TRW),
  B-E shovel unit (Lornex mine),

- for fuel control: fuel recorder (TRW),
- for trip recorders: electronic trip recorder (TRW),
- for transmission control: program selectable switching (Detroit diesel),
- for tire pressure control: tire monitor (Schrader).

The systems for diagnostics control, selected for off-highway vehicle installations are:

- EEC-IV system (Ford) for control of fuel, spark, canister purge, idle speed, self diagnostics, fuel shut-off, and AC power cut-off;
- FMS-1330 system (Argo) for control of fuel consumption, overspeeding, engine operation, driving and stopping habit, excessive engine idling, and RPM,
- TSS control (Dynafloat) for reporting on truck manufacturers problem, field failure, failure under warranty, and quality cost analysis.

The integrated control system combine functional and to some extent diagnostics controls to provide comprehensive monitoring of the vehicle performance. Several systems were investigated, such as:

- TIACS system (TRW) that have several functional and diagnostics units connected to the central serial communication link. The system has a set of truck electronic sub-systems for driver control, operator and vehicle safety, performance monitors and controls, information displays, and vehicle maintenance and diagnostics.
- VMS system (GLI) for monitoring engine drive train, fluid levels, temperatures, electrical outputs, RPM and speed of the vehicle. The system provide information to mine maintenance personnel to assist them in trouble-shooting, recording operating extremes and their duration. This system is presently tested in field environment.
- ETEC system (TRW) provides control for vehicle speed to any preset limit. It also includes the Automatic Truck Control (ATC) unit that consists of the "On-board control" equipment and "Wayside control" equipment. The On-board sensors monitor all critical truck

functions and provide instruction for optimum truck operation. The Wayside equipment includes a buried guidewire, block control units and a central controller which provides predetermined signals to the on-board equipment.

The truck management system introduced recently (1984) to the North Americian market is a total management system that include:

- truck operational/maintenance management control,
- on-board functional sensing and diagnostics,
- truck dispatch system.

The truck management system (OBDAS) developed by Philippi-Hagenbuch, Inc. of Peoria, Illinois is a non-operator dependent system, which automatically provides high technology data, without human error. The "OBDAS" system consists of two body-to-chassis frame rail load sensors, a 3-position micro switch, a mercury tilt switch and a microprocessor. The basic load sensor is an oil field pressure hose with high accuracy pressure transducers on either hose end. An accuracy of the system is in $\pm$2% range. Several sensors and indicators may be added to the basic system, creating a complete truck monitoring unit. Data could be downloaded onto tape installed on board of the truck for later evaluation or transmitted to the central control computer for immediate display.

After evaluating all systems available, decision was made to test the "OBDAS" system in the field for a period of at least six months to determine system accuracy, effectiveness and usefulness. A proposal for a joint project with industry was developed, to access this system in an operational environment of surface coal or oil sands mine in Canada.

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